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Assessment of Industrial Hazardous Waste Practices in the Metal Smelting and Refining Industry. Volume IV. Appendices

Calspan Corp, Buffalo, N Y

Prepared for

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ASSESSMENT OF INDUSTRIAL HAZARDOUS WASTE PRACTICES IN THE METAL SMELTING AND REFINING INDUSTRY

Volume IV

Appendices

This final report (SW-145c.4) describes work performed for the Federal solid waste management programs under contract no. 68-01-2604 and is reproduced as received from the contractor

The report is in four volumes: (I) Executive Summary, (II) Primary and Secondary Nonferrous Smelting and Refining, (III) Ferrous Smelting and Refining, and (IV) Appendices

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16. Abstracts

This report covers primary and secondary metal smelting and refining industries. Characteristics of each industry sector, including plant locations, production capacities, and smelting and refining processes, have been identified and described. Land-disposal or stored residuals have been identified and characterized for physical and chemical properties. State, regional, and national estimates have been made of the total quantities of land-disposed or stored residuals and potentially hazardous constituents thereof. Current methods employed by the primary metals industry for the disposal or storage of process and pollution control residuals on land are described. Methods of residual treatment and disposal considered suitable for adequate health and environmental protection have been provided. Finally, the costs incurred by typical plants in each primary smelting and refining category for current and environmentally sound potentially hazardous residual disposal or storage on land have been estimated.

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Ferrous Smelting and Refining
Nonferrous Smelting and Refining
Secondary Smelting and Refining
Primary Smelting and Refining
Hazardous Wastes
Slags, Sludges, Dust
Lagoons
Open Dump
Disposal Technology
Leaching
Heavy Metals
Lined Lagoons
Soil Sealing - Bentonit
Sludge Solidification
Cyanide
Floride
Oil and Grease

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APPENDIX A

Chemical Analyses of Residuals from Metal Smelting and Refining

This appendix contains the results of chemical analyses of waste samples from various metal smelting and refining industries. Samples were either collected by Calspan personnel at the time of plant visits or collected and shipped to Calspan by industry personnel. Chemical analyses were conducted at the Calspan Corporation laboratory. Analyses of wastes from the following industries are given:

	Table No.
Primary Copper	A- 1
Primary Lead	A- 2
Primary Zinc	A- 3
Primary Aluminum	A- 4
Primary Antimony	A- 5
Primary Mercury	A- 6
Primary Tungsten	A- 7
Secondary Copper	A- 8
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Iron and Steel	A-11
Iron and Steel Foundries	A-12
Ferroalloys	A-13

TABLE A-1 SAMPLE ANALYSES - PRIMARY COPPER PLANTS

Concentration of Potentially Hazardous Constituents (PPM)

Plant	Type of Sample	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Se	Zn
A	Fine Dust From ESP on Converters	---	520	50	280000	0.8	90	110	8000	500	30	28000
	Reverb. Furnace Slag	---	<5	45	10000	0.9	230	10	250	250	40	3700
	Fine Dust From ESP on Reverb. Furn.	---	310	45	240000	2.5	100	35	12000	750	80	44000
	Sludge from Lagoon Receiving Acid Plant Blowdown	---	180	25	22000	5.0	8	10	>12000	800	550	1900
B	Electric Furnace Slag	---	<5	50	3700	0.5	165	5	250	<100	10	8000
C	Reverberatory Furnace Slag	---	10	100	6200	0.7	450	25	100	400	20	7800
D	Converter Slag	---	<5	40	40000	0.5	140	100	200	200	20	1000
	Reverb. Slag	---	<5	160	6100	0.8	170	20	80	100	20	650
	Solids from Acid Plant Blowdown Thickener Overflow	---	<5	30	150000		10	<10	10000	1200	150	120
	Water from Above	6.64	10.5	1.7	390	0.25	5.1	1.8	4.0	<1.	0.30	45
	Solids from Acid Plant Blowdown Thickener Underflow	---	60	90	380000	6.0	72	95	5800	200	40	1000
	Water from Above	1.44	1.1	0.2	3.7	0.20	12.5	4.	6.	<1	0.090	40

- Not analyzed

Table A-2

SAMPLE ANALYSES – PRIMARY LEAD SMELTERS AND REFINERS

PLANT	MATERIAL ANALYZED	CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm)								
		Cd	Cr	Cu	Hg	Pb	Zn	Sb	Tl	Mn
A	FRESH BLAST FURNACE SLAG	10	34	1,850	–	33,500	131,000	–	–	–
	OLD BLAST FURNACE SLAG	88	37	2,330	–	68,500	51,000	–	–	
	SINTER SCRUBBER SLUDGE	900	11	10,400	0.1	164,000	25,600	–	–	–
	LAGOON DREDGINGS (SLAG GRANULATION)	700	28	1,490	–	115,000	132,000	–	–	–
	BAGHOUSE DUST (FROM BLAST FURNACE)	14,000	10	5,350	–	148,000	82,000	–	20	–
B	FRESH BLAST FURNACE SLAG	1,150	37	2,750	–	61,900	110,000	–	–	–
	OLD BLAST FURNACE SLAG	73	79	2,250	–	46,700	160,000	–	–	–
C	FRESH LEAD FUMING SLAG	10	150	1,500	–	25,000	42,000	33	–	14,560
	OLD LEAD FUMING SLAG	5	90	1,600	–	20,000	31,000	20	–	13,500
	BLAST FURNACE SLAG	350	30	1,500	–	94,000	120,000	440	–	11,500
	LAGOON DREDGINGS FROM LEAD SMELTER	640	60	6,200	–	140,000	80,000	3,000	–	2,900
D*	BLAST FURNACE SLAG	–	–	2,600	–	38,000	108,000	–	–	–
E*	BLAST FURNACE SLAG	–	–	2,500	–	35,000	150,000	–	–	–
F*	BLAST FURNACE SLAG	–	–	–	–	25,000	120,000	–	–	–

*DATA FROM BUREAU OF MINES, ROLLA, MISSOURI. ALL OTHER DATA FROM SAMPLES OBTAINED BY CALSPAN CORP.

– NOT ANALYZED

Table A-3

SAMPLE ANALYSES – PRIMARY ZINC SMELTERS AND REFINERS

PLANT	MATERIAL ANALYZED	CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm)						
		Cd	Cr	Cu	Hg	Pb	Tl	Zn
A	GYPSUM CAKE (NEUTRAL COOLING TOWER)	< 10	10	38	–	98	–	27,000
	GYPSUM CAKE (ACID COOLING TOWER)	< 10	9	10	–	1,750	–	30,500
	GYPSUM CAKE (LAND DUMP)	550	11	1,580	–	18,100	–	222,500
	FRESH ANODE SLUDGE	12	10	85	–	170,000	–	12,800
	OLD ANODE SLUDGE (FROM DUMP)	1,400	8	1,900	–	89,000	–	39,200
B	FRESH ACID PLANT SLUDGE	2,000	25	900	9.5	4,350	–	195,000
	OLD ACID PLANT SLUDGE	640	39	700	–	4,280	–	225,000
	FRESH VERTICAL RETORT FURNACE RESIDUE	850	46	4,600	–	2,400	–	107,000
	CADMIUM PLANT RESIDUE (IRON PRESS)	280	24	1,150	–	215,000	< 40	39,000
	OXIDE FURNACE RESIDUE	10	17	810	–	68	–	62,000

– NOT ANALYZED

TABLE A-4

SAMPLE ANALYSES - PRIMARY ALUMINUM PLANTS

Plant	Type of Sample	Concentration of Potentially Hazardous Constituents (PPM) Fluoride	Cyanide	Cu	Zn	Pb	Cr	Cd	Mn	Ni
A	Cast house dust			6200	550	4600	230	<1.0	200	150
	Solids to lime treatment plants	180								
	Water to lime treatment plant	126								
	Spent pot liners(cathodes)	84	1050							
	Shotblasting baghouse dust	26		15,000						
	Lime treated water to primary lagoon	14	<.01*							
	Solids to primary lagoon	14	<2.5							
	Sludge dredged from primary lagoon	67	<2.5							
	Primary lagoon effluent	12								
	Secondary lagoon effluent	16								
B	Spent potliners (cathodes)	44	15							
	Cryolite recovery plant lagoon sediment "black mud"	2.2	92.5							
C	Spent potliners (cathodes)	49.6	58							
	Spent anode dust	120								
	Lagoon sludge (line scrubber water -lagoon no longer in use	118								
	Shotblasting baghouse dust			5.6×10^5	320	40	620			
D	Spent potliners (cathodes)	186	<2.5							
	Cryolote recovery plant lagoon sediment "black mud"	1.0	<2.5							

*The use of < indicates that there is no positive detection of cyanide; if present it is at lower concentration than indicated value.

TABLE A-5

SAMPLE ANALYSES - PRIMARY ANTIMONY PLANTS

Plant	Type of Sample	Concentration of Potentially Hazardous Constituents (PPM)								
		Sb	Pb	Cu	Zn	Ni	Mn	Cr	As	Cd
A	Blast furnace slag (Pyrometallurgical)	18,000	66	50	500	-	-	-	-	-
B	Anolyte Sludge	27,000	5	50	2	5	21	32	16	1.0

- not analyzed

TABLE A-6

SAMPLE ANALYSES - PRIMARY MERCURY

Plant	Type of Sample	Concentration of Potentially Hazardous Constituents (PPM)								
		Hg	Zn	Sb	Cd	Pb	Cr	Cu	Mn	Ni
A	Fresh calcine residue	1.5	50	250	<5	100	410	15	850	2700
A	Old calcine residue	2.5	110	100	<5	200	450	850	1200	2500

TABLE A-7

SAMPLE ANALYSIS - PRIMARY TUNGSTEN PLANT

Plant	Type of Sample	Concentration of Potentially Hazardous Constituents (PPM)			
		Cu	Zn	Pb	Sb
A	Digestion residue	38,000	850	90	<10

Table A-8
SAMPLE ANALYSES–SECONDARY COPPER SMELTERS

PLANT	MATERIAL ANALYZED	CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm)								
		Cd	Cr	Cu	Mn	Ni	Pb	Sb	Sn	Zn
A	BLAST FURNACE SLAG	< 5	20	12,000	7,000	260	2,800	< 100	–	75,000
B	WATER TREATMENT SLUDGE	10	94,000	170,000	–	16,600	900	–	20,000	1,850
	BRASS CASTING DROSS	160		340,000	–	4,100	–	–	17,000	330,000
	NICKEL BRASS DROSS	160		420,000	–	1,200	–	–	1,000	210,000
	CHROME BRASS DROSS	25	15,500	100,000	–	–	–	–	180,000	460
	BAG HOUSE DUST	5,000		47,000	–	–	12,000	–	7,500	520,000

– NOT ANALYZED

Table A-9
SAMPLE ANALYSES–SECONDARY LEAD SMELTERS

PLANT	MATERIAL ANALYZED	CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm)								
		Zn	Cd	Cr	Cu	Mn	Ni	Pb	Sb	Sn
A HARD AND SOFT LEAD	SCRUBBER SLUDGE	25	340	30	20	120	5	53,000	1,100	–
	WASTEWATER TREATMENT SLUDGE	140	10	35	80	74	5	2,700	250	–
B WHITE METAL (LEAD-TIN ALLOY)	SMELTER FURNACE SLAG	500	5	500	120	800	5	50	100	5,000
	SMELTER FURNACE DUST*	120,000	900	150	400	5	5	120,000	1,800	117,000
C WHITE METAL (LEAD-TIN ALLOY)	WHITE METAL DROSS*	4,700	–	–	–	–	–	160,000	–	5,000
	WHITE METAL DROSS*	2,600	–	–	–	–	–	145,000	–	90,000

*THIS MATERIAL IS RECYCLED

–NOT ANALYZED

Table A-10
SAMPLE ANALYSES – SECONDARY ALUMINUM PLANTS

PLANT	MATERIAL ANALYZED	CONCENTRATION OF POTENTIALLY HAZARDOUS CONSTITUENTS (ppm)								
		Al	Cl	Cr	Cu	F	Na	Sn	Pb	Zn
A	SMELTING DROSS	210,000	–	20	3,300	–	4,000	–	5,800	2,300
B	SMELTING DROSS	340,000	–	900	4,800	114	–	–	540	4,300
	CASTING DROSS	280,000	–	280	27,000	–	–	17,000	380	2,600
	BAGHOUSE DUST (INCOMPLETE CYCLE)	96,000	–	20	2,600	630	–	–	80	160
	BAGHOUSE DUST (COMPLETE CYCLE)	90,000	–	20	230	98	–	–	200	380
C	SMELTING DROSS	120,000	–	190	5,300	–	11,000	–	1,050	4,200
	WET SCRUBBER SLUDGE	9,000	–	20	1,250	< .01	–	–	140	6,500
D	SLAG FURNACE	17,500	450,000	60	310	–	190,000	–	300	240

– NOT ANALYZED

TABLE A-11 Sample Analyses - Iron and Steel Plants

Sample Description	Sample Period*	Chemical Analysis (ppm) Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
BOF Slag	A	870	34.2	36,000	<10	<10	<5	**	5000	-	-
	B	1300	30.0	48,000	<10	25	<5	- -	3000	-	-
	C	2310	41.7	49,000	<10	<10	<5	-	4200	-	-
	D	1500	47.7	48,500	<5	50	<5	-	1000	-	-
Blast Furnace Slag	A	43	18.3	2,400	<5	<10	<5	-	2000	-	-
	B	67	21.8	2,500	<5	<10	20	-	1120	-	-
	C	53	23.3	2,200	<5	<10	<5	-	2140	-	-
	D	56	19.7	2,700	<5	<10	<5	-	1300	-	-
Ammonia Still Lime Pit	A	43	35.0	550	5	33	550	<0.25	-	19,000	7.9
	B	43	26.7	550	10	<10	700	3.0	-	34,000	6.8
	C	80	22.5	550	15	67	730	<0.25	-	40,000	3.4
	D	53	23.3	500	8	33	710	43.1	-	32,000	8.1
Reladling Baghouse Dust	A	176	67.0	2,400	110	117	950	-	-	-	-
	B	187	65.0	2,800	110	180	980	-	-	-	-
	C	200	40.0	2,450	100	42	400	-	-	-	-
	D	176	46.7	2,400	90	42	670	-	-	-	-
Pickle Liquor (solid phase)	A	1710	60	6,040	280	9	10,700	-	-	-	-
	B	1000	70	3,050	273	<18	9,300	-	-	-	-
	C	1590	133	4,830	750	167	36,700	-	-	-	-
	D	870	64	2,520	320	248	16,400	-	-	-	-
Pickle Liquor (liquid phase)	A	6.5	8.6	220	9.5	<0.2	1	-	-	39	-
	B	8.1	9.6	240	8.0	<0.2	1	-	-	78	-
	C	5.5	7.6	180	9.4	<0.2	1	-	-	19	-
	D	6.0	8.6	200	11.5	<0.2	1	-	-	43	-
Water Control Station #7 Final Thickened Sludge	A	107	80	1,100	170	83	15,000	-	839	138,000	-
	B	127	87	1,500	180	117	18,000	-	960	47,000	-
	C	107	88	1,350	190	130	20,000	-	-	169,000	-
	D	123	68	800	170	83	17,000	-	580	116,000	-

- Not Analyzed

Sample Analyses - Plant A (cont.)

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
Secondary Settling Sludge	A	160	148	2,300	250	92	400	-	776	-	-
	B	133	125	1,800	200	42	330	-	420	-	-
	C	140	143	1,850	210	35	360	-	680	-	-
	D	137	140	1,790	200	82	360	-	600	-	-
Blast Furnace Sludge	A	85	48.0	1,250	90	3,000	70,000	-	1,160	-	-
	B	147	61.3	1,900	100	2,000	30,000	-	760	-	-
	C	85	38.3	2,250	80	1,400	9,900	-	680	-	-
	D	93	30.0	1,900	80	4,000	40,000	-	-	-	-
BOF Sludge	A	385	67.0	6,000	150	<10	340	-	4,400	-	-
	B	338	58.0	5,800	150	42	500	-	760	-	-
	C	324	85.0	7,550	160	83	250	-	4,560	-	-
	D	324	64.2	9,000	780	67	600	-	741	-	-
Mill Primary Settling Pit	C	878	380	5,050	400	79	90	-	-	-	-
	D	919	180	5,050	580	<10	70	-	-	-	-
Mill Scarfer Primary Settling Pit	C	1600	80.8	7,900	170	<10	35	-	-	-	-
	D	1800	97.0	9,000	250	<10	15	-	-	-	-

* Sampling Periods:
  - A December 9 - 13
  - B December 16 - 20
  - C December 30 - January 3
  - D January 6 - 10

- Indicates no analysis made

Sample Analyses - Plant B

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
Soaking Pit Slag	A	400	330	6,800	150	860	58	**	-	-	-
	B	350	400	7,300	170	400	120	-	-	-	-
	C	450	330	6,200	140	2,200	80	-	-	-	-
	D	500	320	6,200	130	2,600	150	-	-	-	-
Open Hearth Slag	A	2,000	25	61,000	14	35	<5	-	2,100	-	-
	B	1,800	26	60,000	14	165	<5	-	1,000	-	-
	C	2,200	30	42,000	19	170	<5	-	4,900	-	-
	D	2,300	37	39,000	31	260	<5	-	2,040	-	-
Electric Furnace Slag	A	7,000	80	57,000	64	30	<5	-	3,260	-	-
	B	7,600	86	50,000	66	10	<5	-	1,130	-	-
	C	5,500	91	51,000	84	75	15	-	3,490	-	-
	D	3,900	84	49,000	40	185	400	-	2,040	-	-
Electric Furnace Baghouse Dust	A	1,300	1,800	38,000	500	20,000	75,300	-	2,940	-	-
	B	1,500	2,400	39,000	320	22,000	75,800	-	2,040	-	-
	C	1,200	1,900	40,000	340	21,000	54,000	-	2,940	-	-
	D	1,400	1,900	45,000	400	25,000	70,000	-	1,700	-	-
Open Hearth E.S.P. Dust	A	280	250	4,000	500	2,700	850	-	1,370	-	-
	B	550	550	9,700	400	11,000	14,500	-	1,000	-	-
	C	350	220	3,000	480	2,650	1,000	-	600	-	-
	D	930	400	12,000	500	4,000	7,600	-	600	-	-
Grinder Baghouse Dust	A	3,000	1,850	5,500	4,340	125	45	-	-	-	-
	B	19	400	1,300	300	50	25	-	-	-	-
	C	1,200	1,000	7,200	900	60	50	-	-	-	-
	D	770	550	10,100	750	35	20	-	-	-	-
Grit Blast Dust	A	1,300	2,000	8,600	800	48	50	-	-	-	-
	B	8	500	156	200	30	40	-	-	-	-
	C	900	750	6,000	750	35	42	-	-	-	-
	D	28	500	3,000	300	9	45	-	-	-	-

Sample Analyses - Plant B (cont.)

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
Decanter Tar Sludge (Coke Byproduct Plant)	A	-	-	-	-	-	-	8.7	-	144,000	2,121
	B	4	1	44	<10	30	20	9.8	-	278,000	3,127
	C	-	-	-	-	-	-	1.3	-	297,000	1,711
	D	-	-	-	-	-	-	3.1	-	182,000	1,715
Water Treatment Plant 1&2 Filter Cake	A	50	3	<1	<10	<10	<5	-	-	54,000	-
	B	400	550	5,500	650	450	1,000	-	-	34,000	-
	C	370	520	5,200	620	550	900	-	-	104,000	-
	D	11	3	<1	<10	<10	<5	-	-	89,000	-
Water Treatment Plant 1&2 Wire Mill (liquid + solid phase)	A	1.6	0.14	24.0	0.08	0.08	6.3	-	-	-	-
	B	0.52	0.21	1.4	0.13	0.17	5.0	-	-	-	-
	C	1.1	0.32	39.0	0.23	0.12	9.0	-	-	-	-
	D	0.9	0.16	2.1	0.58	0.12	23.5	-	-	-	-
Water Treatment Plant 1&2 CCA (liquid + solid phase)	A	0.5	0.22	0.42	0.1	0.12	0.3	-	-	-	-
	B	0.9	0.22	0.62	0.09	0.03	0.5	-	-	-	-
	C	0.9	0.18	0.51	0.07	0.05	0.4	-	-	-	-
	D	0.8	0.08	0.20	0.05	0.04	0.49	-	-	-	-
Pickle Liquor (Solid phase)											
low carbon	A+B	410	740	14,400	60	1,840	520	-	-	-	-
low carbon	C+D	195	330	15,600	52	4,500	180	-	-	-	-
alloy + high carbon	B	98	75	860	66	115	150	-	-	-	-
CCA	C	5,100	1,050	2,500	640	7	125	-	-	-	-
Pickle Liquor (Liquid phase)											
low carbon	A+B	8.0	1.0	180	18	1.85	20	-	-	47	-
low carbon	C+D	11.0	1.4	450	23	4.0	65	-	-	63	-
alloy + high carbon	B	16.0	1.1	330	32	2.5	15	-	-	8	-
CCA	C	9.3	3.1	360	36.4	0.28	30	-	-	88	-

- No Analysis made

Sample Analyses - Plant C

Chemical Analysis (ppm)

Sample Description	Sample Period*	Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
BOP Slag	A	1,750	60	45,000	<10	34	2	**	4,560	-	-
	B	1,150	43	44,500	<10	34	<2	-	4,720	-	-
	C	1,700	47	44,500	<10	4.8	<2	-	8,400	-	-
	D	2,400	38	46,500	<10	30	<2	-	5,500	-	-
Electric Furnace Slag	A	6,300	120	79,500	21	74	600	-	1,700	-	-
	B	6,000	67	67,800	13	38	4	-	2,800	-	-
	C	7,800	56	80,500	<5	4.5	<2	-	1,400	-	-
	D	8,500	90	81,000	<10	61	<2	-	500	-	-
Soaking Pit Slag	A+B	380	300	3,500	90	3.0	5	-	-	-	-
	C+D	580	400	5,100	70	7.2	15	-	-	-	-
Blast Furnace Slag	A	30	26	2,600	<10	12	<2	-	1,400	-	-
	B	38	20	3,750	<10	42	15	-	940	-	-
	C	40	23	3,750	<10	56	10	-	1,440	-	-
	D	48	23	4,100	<10	42	12	-	2,220	-	-
BOP Centrifuge Cake	A	260	210	8,500	58	2,800	6,500	-	2,100	-	-
	B	10,500	270	11,000	140	2,000	6,000	-	3,090	-	-
	C	380	190	8,500	38	1,650	3,500	-	2,640	-	-
	D	420	190	11,500	58	2,150	4,000	-	1,840	-	-
Electric Furnace Drum Filter Cake	A	810	580	28,000	200	2,300	8,900	-	7,500	-	-
	B	12,000	590	34,000	210	2,800	4,300	-	1,700	-	-
	C	2,800	660	44,000	300	1,800	8,300	-	4,000	-	-
	D	760	710	43,800	230	2,900	3,850	-	2,800	-	-
Blast Furnace Sludge	A	30	44	2,600	6	500	1,400	<0.25	1,140	-	1.7
	B	32	50	2,700	10	450	1,100	7.4	1,140	-	2.1
	C	36	44	2,750	10	550	1,450	3.0	2,260	-	1.8
	D	39	56	2,600	7	700	1,500	9.6	1,100	-	2.4

Sample Analyses - Plant C (cont.)

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	F	Oil & Grease	Phenol
Central Treatment Plant Clarifier Sludge	A	320	440	7,000	150	1,780	2,800	-	1,140	106,000	-
	B	1,200	440	9,800	145	1,500	1,600	-	800	104,000	-
	C	1,200	400	6,000	150	1,000	2,700	-	1,040	98,000	-
	D	700	380	8,000	147	1,250	1,250	-	700	87,000	-
Effluent Water from Scale Settling Pit for 96" Plate Mill (liquid + solid phase)	A	0.3	0.04	0.05	<0.03	<0.1	0.18	-	-	-	-
	B	0.3	0.15	0.11	<0.03	0.13	0.15	-	-	-	-
	C	0.31	0.04	0.11	<0.03	<0.1	0.15	-	-	-	-
	D	0.19	0.07	0.07	<0.03	<0.1	0.15	-	-	-	-
Effluent Water from Scale Settling Pit for Continuous Casting Mill (liquid+solid phase)	A	0.26	0.13	0.13	<0.03	0.15	0.15	-	-	-	-
	B	0.15	0.06	0.07	<0.03	<0.1	0.06	-	-	-	-
	C	0.15	0.05	0.13	<0.03	<0.1	0.09	-	-	-	-
	D	0.20	0.04	0.07	<0.03	<0.1	0.1	-	-	-	-
Effluent Water from Scale Settling Pit for Structural Mill (liquid + solid phase)	A	0.11	0.25	0.44	0.16	<0.1	0.13	-	-	-	-
	B	0.16	0.12	0.3	0.05	<0.1	0.08	-	-	-	-
	C	0.80	0.15	0.3	0.13	0.16	0.16	-	-	-	-
	D	0.21	0.26	0.4	0.15	<0.1	0.09	-	-	-	-
Effluent Water from Scale Settling Pit for 30" Plate Mill (liquid + solid phase)	A	0.16	0.06	0.16	<0.03	<0.1	0.37	-	-	-	-
	B	0.16	0.02	0.1	<0.03	<0.1	0.06	-	-	-	-
	C	0.21	0.06	0.07	<0.03	<0.1	0.04	-	-	-	-
	D	0.21	0.09	0.11	<0.03	<0.1	0.08	-	-	-	-
Effluent Water from Scale Settling Pit for Alloy Bar Mill (liquid + solid phase)	A	0.15	0.44	0.19	0.1	0.2	0.11	-	-	-	-
	B	0.16	0.12	0.09	<0.03	<0.1	0.07	-	-	-	-
	C	0.12	0.17	0.13	<0.03	0.16	0.05	-	-	-	-
	D	0.21	0.12	0.09	<0.03	<0.1	0.07	-	-	-	-

- No analysis made

Sample Analyses - Plant D

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	pH
Blast Furnace Flue Dust	A	170	230	2,700	130	850	250	1.15	-	0.97	-
	B	120	300	3,300	100	750	250	1.96	-	0.34	-
	C	150	190	3,200	120	600	250	1.19	-	1.20	-
	D	135	210	3,300	76	800	900	5.81	-	0.39	-
Clarifier Sludge Central Treatment Plant	A	150	110	3,400	90	3,000	1,700	0.40	220,000	2.53	-
	B	130	110	3,000	100	2,500	1,600	1.18	157,000	0.23	-
	C	75	110	2,500	80	2,200	1,500	<0.25	133,000	0.58	-
	D	110	140	2,500	96	2,300	1,200	<0.25	45,400	0.86	-
Mill Scale - 18" Bar Mill	A	300	120	2,700	190	23	22	-	30,800	-	-
	B	190	100	2,700	110	50	34	-	53,900	-	-
	C	200	150	3,000	100	50	34	-	59,700	-	-
	D	240	110	2,300	128	33	9	-	7,300	-	-
Bar Mill Scale Pit (8", 10", 18" Mills)	A	660	350	4,500	270	340	30	-	204,000	-	-
	B	570	330	4,700	190	450	30	-	169,000	-	-
	C	340	230	3,200	160	970	25	-	174,000	-	-
	D	270	230	2,300	120	330	45	-	88,100	-	-
BOF ESP Dust	A	330	200	12,000	140	8,000	3,800	-	-	-	-
	B	310	200	11,600	90	8,200	2,600	-	-	-	-
	C	350	220	11,000	130	6,700	3,400	-	-	-	-
	D	270	190	11,000	100	6,500	3,600	-	-	-	-
Baghouse Kish (metal pouring BOF)	A	180	120	4,000	70	750	2,000	-	-	-	-
	B	-	-	-	-	-	-	-	-	-	-
	C	-	-	-	-	-	-	-	-	-	-
	D	105	50	3,000	15	67	130	-	-	-	-
Steel Conditioning Scarfing Scale	A	330	180	7,500	140	30	42	-	-	-	-
	B	400	160	5,800	130	60	30	-	-	-	-
	C	390	160	5,500	140	60	31	-	-	-	-
	D	330	130	3,500	96	60	8	-	-	-	-

Sample Analyses - Plant D (cont.)

Sample Description	Sample Period	Chemical Analysis (ppm) Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	pH
Bar Finishing Pickle Liquor	A	14.	2.2	210.	9.0	0.5	1.0	-	30.5	-	<1
	B	9.6	2.0	170.	8.0	1.0	1.0	-	25.5	-	<1
Steel Conditioning Pickle Liquor	C	10.	2.5	180.	4.1	2.0	1.3	-	5.0	-	<1
	D	32.	2.7	205.	15.	2.0	2.0	-	95.0	-	<1
BOF Slag	A	1,400	15	35,000	5.2	<10	<3	-	-	-	-
	B	1,400	13	27,000	3.5	<10	<3	-	-	-	-
	C	1,400	13	21,000	4	<10	<3	-	-	-	-
	D	1,500	22	24,000	12	<10	<3	-	-	-	-

- No analysis made

Sample Analyses - Plant E

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	Sn	NH_3
Blast Furnace Flue Dust	A	50	20	31,000	27	67	140	1.46	-	2.01	-	-
	B	37	13	12,500	18	47	90	8.46	-	0.1	-	-
	C	33	13	18,000	20	73	130	3.12	-	0.36	-	-
	D	59	17	18,500	20	73	280	1.60	-	0.99	-	-
Blast Furnace Filter Cake	A	30	20	8,500	22	400	780	5.34	-	0.60	-	-
	B	22	24	6,700	31	600	850	<0.7		0.44		
	C	22	17	6,700	22	420	860	7.21	-	0.21	-	-
	D	20	14	8,100	20	420	880	0.62	-	0.14	-	-
Plate Mill Scale	A	80	170	4,800	200	<10	9	-	2,700	-	-	-
	B	90	220	5,200	220	<10	11	-	7,000	-	-	-
	C	95	210	5,700	240	<10	20	-	18,500	-	-	-
	D	75	180	5,200	190	<10	9	-	4,400	-	-	-
Hot Strip Mill Scale	A	27	80	2,700	78	<10	9	-	5,850	-	-	-
	B	23	80	2,500	78	<10	9	-	5,040	-	-	-
	C	20	90	2,500	90	<10	11	-	8,600	-	-	-
	D	21	90	2,500	90	<10	9	-	27,000	-	-	-
BOF Fines	A	55	110	14,800	78	600	890	-	-	-	-	-
	B	60	120	15,600	90	650	960	-	-	-	-	-
	C	60	130	15,200	80	620	960	-	-	-	-	-
	D	60	130	15,200	100	500	920	-	-	-	-	-
BOF Sands	A	50	60	10,700	50	17	58	-	-	-	-	-
	B	50	90	11,100	33	40	260	-	-	-	-	-
	C	50	70	11,900	44	23	60	-	-	-	-	-
	D	40	30	10,400	33	<10	40	-	-	-	-	-
BOF Slag	A	50	23	47,500	11	<10	13	-	-	-	-	-
	B	42	43	47,500	9	<10	13	-	-	-	-	-
	C	75	23	47,500	15	<10	12	-	-	-	-	-
	D	39	19	43,000	9	<10	16	-	-	-	-	-

Sample Analyses - Plant E (cont.)

Sample Description	Sample Period	Chemical Analysis (ppm) Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	Sn	NH_3
BOF Kish	A	20	16	5,600	18	87	230	-	-	-	-	-
	B	16	17	5,200	15	21	170	-	-	-	-	-
	C	18	16	4,800	18	27	530	-	-	-	-	-
	D	18	19	5,400	20	37	540	-	-	-	-	-
Tin Plate Sludge	A	29	1,100	240	170	700	630	-	-	-	66,500	-
	B	27	2,500	190	72	720	660	-	-	-	67,500	-
	C	35	3,500	430	310	1,080	880	-	-	-	62,500	-
	D	54	9,000	480	700	1,060	960	-	-	-	55,000	-
Treatment Plant Sludge	A	63	190	10,000	140	300	880	-	-	-	-	-
	B	60	170	8,300	130	260	770	-	-	-	-	-
	C	73	190	8,900	160	260	870	-	-	-	-	-
	D	71	170	7,000	130	240	730	-	-	-	-	-
Waste Ammonia Liquor	A	-	-	-	-	-	-	28.4	40	161	-	250
	B	-	-	-	-	-	-	36.7	88	210	-	250

- No analysis made

Sample Analyses - Plant F

Sample Description	Sample Period	Chemical Analysis (ppm) Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	NH_3
Open Hearth ESP Dust	A	580	1,200	3,400	190	18,400	700,000	-	-	-	-
	B	618	1,300	3,600	230	15,000	250,000	-	-	-	-
	C	659	3,200	3,900	320	15,000	130,000	-	-	-	-
	D	560	1,700	3,300	230	18,000	130,000	-	-	-	-
Open Hearth Slag	A	5,000	47	47,000	11	<10	77	-	-	-	-
	B	2,200	54	40,000	32	<10	80	-	-	-	-
	C	2,100	50	38,500	26	<10	20	-	-	-	-
	D	4,300	50	43,000	18	<10	<3	-	-	-	-
Electric Furnace Baghouse Dust	A	900	1,700	40,000	170	32,000	240,000	-	-	-	-
	B	840	3,300	39,000	207	48,000	174,000	-	-	-	-
	C	770	3,400	39,500	217	46,000	166,000	-	-	-	-
Electric Furnace Slag	A	3,400	73	49,000	9	<10	59	-	-	-	-
	B	2,700	100	50,000	26	10	110	-	-	-	-
BOF Wet Scrubber Slurry	A	440	350	17,000	100	16,400	16,000	-	-	-	-
	B	370	286	14,100	133	13,000	14,000	-	-	-	-
	C	180	257	11,400	167	11,000	10,000	-	-	-	-
	D	400	270	13,200	100	15,200	15,000	-	-	-	-
BOF Slag	A	2,500	23	43,000	46	< 10	20	-	-	-	-
	B	1,400	32	49,000	23	< 10	200	-	-	-	-
	C	1,200	20	48,000	17	10	56	-	-	-	-
	D	1,700	68	42,000	17	< 10	< 3	-	-	-	-
Structural Mill Scale	A	200	300	3,400	130	30	38	-	5,900	-	-
	B	150	257	3,200	150	<10	19	-	3,750	-	-
	C	210	243	4,100	133	62	60	-	4,580	-	-
	D	200	330	4,700	150	300	12	-	27,900	-	-

Sample Analyses - Plant F (cont.)

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	NH_3
Ammonia Still Lime Sludge	A	-	-	-	-	-	-	343	14,900	670	<6.25
	B	-	-	-	-	-	-	1,440	104,000	1,160	< 6.25
	C	-	-	-	-	-	-	1,630	30,700	1,910	<6.25
	D	-	-	-	-	-	-	1,940	12,100	1,550	252
80" Hot Strip Mill Clarifier Sludge	A	170	220	2,400	240	100	60	-	79,700	-	-
	B	230	257	3,400	300	230	40	-	40,100	-	-
	C	210	229	5,000	240	3,600	2,550	-	9,040	-	-
	D	180	220	2,300	230	280	24	-	52,300	-	-

- No analysis made

Sample Analyses - Plant G

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	pH
Blast Furnace Flue Dust	A	80	30	3,300	22	80	1,000	26.2	-	9.87	-
	B	75	30	3,000	40	80	900	8.67		1.09	-
	C	100	34	3,600	51	104	1,020	37.8	-	0.14	-
	D	100	31	3,200	67	104	980	12.3	-	0.35	-
Blast Furnace Sludge	A	65	40	3,000	21	1,100	5,000	30.6	-	1.18	-
	B	55	40	3,000	30	900	3,600	7.54	-	1.22	-
	C	65	41	2,700	41	1,500	9,000	22.1	-	0.87	-
	D	71	31	2,500	45	1,200	10,100	7.56	-	0.24	-
Open Hearth Slag	A	1,800	60	40,000	10	< 10	70	-	-	-	-
	B	1,900	90	30,000	40	< 10	180	-	-	-	-
	C	1,300	69	35,000	24	23	80	-	-	-	-
	D	1,400	59	37,000	45	< 10	56	-	-	-	-
Open Hearth ESP Dust	A	500	830	3,600	200	9,000	15,000	-	-	-	-
	B	550	1,100	3,500	230	15,000	17,000	-	-	-	-
	C	580	1,050	4,100	250	14,000	37,000	-	-	-	-
	D	660	1,800	3,600	233	15,000	53,000	-	-	-	-
Blooming Mill Scale	A	280	250	4,500	160	50	25	-	2,500	-	-
	B	320	280	8,000	90	50	60	-	5,400	-	-
	C	140	286	12,700	167	< 10	16	-	6,460	-	-
	D	210	510	4,300	250	< 10	18	-	2,330	-	-
Hot Strip Mill Waste Pickle Liquor	A	2.5	2.0	90.	6.0	< 0.1	0.65	-	44.5	-	< 1
	B	2.0	1.7	69.	4.7	< 0.1	0.6	-	50.0	-	< 1
	C	3.8	2.57	111.	7.0	< 0.1	0.67	-	134	-	< 1
	D	3.8	2.0	100.	6.7	0.1	1.0	-	150	-	< 1
Surface Glaze Grinder Waste	A	50	340	1,500	160	15	850	-	-	-	-
	B	75	470	1,800	190	15	1,400	-	-	-	-
	C	71	370	1,270	183	17	3,700	-	-	-	-
	D	82	490	1,500	250	23	1,400	-	-	-	-
South Side Cold Finishing Waste Pickle Liquor	A	10.	10.	190.	7.7	3.5	6.0	-	71.0	-	< 1
	B	19.	30.	185.	13.	3.5	1.6	-	253	-	< 1
	C	9.5	25.	157.	5.0	2.85	3.0	-	141	-	< 1
	D	9.4	45.	182.	6.0	3.23	1.1	-	115	-	< 1

Sample Analyses - Plant H

Sample Description	Sample Period	Chemical Analyses (ppm) Cr	Cu	Mn	Ni	Pb	Zn	Oil & Grease	pH
Electric Furnace Slag	A	3,800	18	57,000	135	<10	60	-	-
	B	1,900	39	37,000	51	<10	<3	-	-
Electric Furnace Baghouse Dust (wet)	A	2,700	550	55,000	3,750	2,000	2,500	-	-
	B	1,800	520	48,000	3,000	2,000	3,800	-	-
BOP Slag	A	1,400	16	38,500	31	<10	<3	-	-
	B	1,300	17	40,500	28	<10	<3	-	-
BOP Sludge	A	310	114	11,400	133	700	440	-	-
	B	220	114	11,400	102	2,000	800	-	-
Soaking Pit Slag	A	130	67	3,200	80	<10	33	-	-
	B	190	79	3,900	102	<10	13	-	-
46" Primary Mill Scale	A	870	143	6,400	533	<10	19	55,600	-
	B	580	114	5,500	167	<10	22	10,600	-
Waste Pickle Liquor	A	48.	8.0	179.	105.	<0.1	7.0	11	1.21
	B	69.	6.0	280.	135.	<0.1	26.	88	<1
Grinder Dust - Conditioning Bldg.	A	980	129	6,300	330	<10	9	-	-
	B	3,700	157	6,100	3,200	<10	40	-	-

- No analysis made

Sample Analyses - Plant I

Chemical Analysis (ppm)

Sample Description	Sample Period	Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol
Melt Shop Sludge	A	1,100	1,500	30,000	480	12,000	18,000	-	-	-
	B	980	1,700	27,000	580	11,000	18,000	-	-	-
	C	1,850	1,600	30,000	900	16,600	30,000	-	-	-
	D	1,190	1,700	36,000	470	13,800	17,000	-	-	-
Electric Furnace Slag	A	2,500	90	20,500	80	<10	10	-	-	-
	B	2,470	90	19,000	40	<10	18	-	-	-
	C	3,700	110	27,000	170	<10	<3	-	-	-
	D	4,000	70	34,000	56	<10	<3	-	-	-
Stainless Steel Processing Sludge (Plant No. 2)	C	23,500	370	560	2,700	<10	48	-	-	-
Stainless Processing Grinder Dust (Plant No. 2)	C	37,500	500	2,300	27,000	<10	8	-	-	-
Combined Sludge Disposal (at Neutralization Plant)	A	300	360	220	220	140	900	8.30	11,000	<0.25
	B	2,300	280	460	880	45	1,100	<0.25	31,400	4.80
	C	650	470	650	840	250	880	11.3	68,300	0.65
	D	3,200	500	1,300	6,200	330	380	17.9	32,900	1.49
Slab Mill Grinder Dust	A	42,000	1,600	12,000	30,000	<10	18	-	-	-
	B	125,000	1,700	10,500	70,000	<10	30	-	-	-
	C	100,000	1,600	10,500	63,000	<10	22	-	-	-
	D	13,000	1,300	13,200	8,700	<10	24	-	-	-
Slab Mill Scale	A	490	1,400	7,000	1,200	140	15	-	5,000	-
	B	270	560	3,800	530	130	15	-	2,500	-
	C	300	900	2,200	730	200	50	-	6,000	-
	D	240	600	3,500	630	20	140	-	14,100	-
Hot Strip Mill Scale	A	200	540	2,400	430	220	150	-	29,700	-
	B	260	750	1,300	1,300	100	35	-	29,000	-
	C	600	770	1,200	6,500	300	24	-	20,300	-
	D	290	800	1,000	2,700	700	25	-	52,600	-

Sample Analyses - Plant J

Sample Description	Sample Period	Chemical Analysis (ppm) Cr	Cu	Mn	Ni	Pb	Zn	CN	Oil & Grease	Phenol	Sn
Tin Mill Sludge	A+B	8,400	160	2,500	130	320	5,000	-	-	-	24,000
	C+D	8,000	130	2,400	120	250	5,400	-	-	-	45,000
C and E Lagoon Sludge		340	160	2,000	130	400	1,800	25.2	47,800	0.47	-
BOF Scrubber Sludge	A	110	250	5,700	70	7,700	47,000	-	-	-	-
	B	100	220	5,000	60	5,900	38,000	-	-	-	-
	C	160	160	6,000	65	4,200	29,000	-	-	-	-
	D	120	230	5,700	80	5,300	27,000				
Hot Strip Mill Scale	A+B	40	190	2,300	90	<10	<3	-	8,070	-	-
	C+D	44	200	2,200	120	<10	18	-	50,700	-	-
Blooming Mill Scale	A+B	60	210	3,300	90	43	8	-	2,830	-	-
	C+D	60	130	3,700	70	43	<3	-	8,830	-	-

- No analysis made

TABLE A-12

Sample Analyses - Iron and Steel Foundries

Plant	Material Analyzed	Concentration of Potentially Hazardous Constituents (ppm)							
		Mn	Zn	Cd	Pb	Cu	Ni	Cr	Phenol
A	mold, pour, and shakeout wet collector system sludge	375	250	2.3	130	150	-	50	-
	cleaning room baghouse dust	4200	200	2.0	<10	950	-	200	-
	baghouse dust from sand reclaimer	41	30	<1.0	15	7.0	-	41	-
	furnace slag	5200	42	1.0	16	52	-	150	-
B	burned core sand	230	7	-	480	26	200	18	1.73
	shotblast cleaning baghouse dust	2060	210	-	840	40	150	100	-
C	Cupola furnace slag	760	10	-	<10	18	10	17	-
	cyclone dust from cupola	870	500	-	130	90	32	21	-
	baghouse dust from cupola	19,000	7000	-	310	300	60	100	-
	burned sand	29	6	-	<10	6	4	3	1.01
	shotblast cleaning baghouse dust	6,700	53	-	21	90	130	150	-

- Not Analyzed

TABLE A-13 SAMPLE ANALYSES - FERROALLOY PLANTS

Type of Ferroalloy	Type of Sample	Concentration of Potentially Hazardous Constituent (PPM)								
		CO	Cr	Cu	Pb	Zn	Mn	Ni	Cd	F
Ferrochrome Silicon	Electric furnace baghouse dust	-	41	45	-	700	700	-	-	-
	furnace slag	-	2140	18	-	150	500	-	-	-
Ferronickel	Glasswool from slag granulation process	87	2320	36	-	100	900	1540	-	-
	Ferrosilicon furnace baghouse dust	82	160	2180	-	1300	1500	3250	-	-
	Reject ore screening	235	27	7	-	50	900	5400	-	-
	Granulated slag	104	321	50	-	100	1100	1850	-	-
		159	2140	23	-	125	2000	4100	-	-
	Skull plant tailings	47	380	21	-	500	500	1330	-	180
Silicomanganese and Ferromanganese	Silicomanganese slag	-	27	23	20	<20	70,000	-	-	-
	Silicomanganese furnace baghouse dust	-	9	36	3200	8000	90,000	-	-	-
	Ferromanganese furnace baghouse dust	-	32	200	6000	45,000	155,000	-	-	-
	Water phase of ferro-manganese baghouse dust slurry	-	0.05	0.05	2.0	1.7	0.12	<0.05	<0.05	-
	Ferromanganese furnace scrubwater solids	-	18	50	5000	35,000	20,000	-	-	-

- Not Analyzed

TABLE A-13 (cont.)

Types of Ferroalloys	Type of Sample	Concentration of Potentially Hazardous Constituent (PPM) Cr	Cu	Pb	Zn	Mn	CN
Silicomanganese	Electric furnace scrubwater	24,800	210	8,900	16,400	232,000	0.02
	Lagoon dredgings (#3)	1,070	44	3,500	900	60,000	-
	Acid waste stream after liming	2,680	27	210	50	16,000	-
	Solids from slag concentrator lagoon	3,390	14	10	100	70	-
	Furnace #1 scrubwater solids (from settling pit)	45	82	25,000	10,000	300,000	-
Ferrochrome	Ferrochrome Slag concentrator residue (coarse fraction)	4,540	23	< 10	25	500	-
	Solids from dredged slag concentrator lagoons	3,210	14	20	70	300	-
	Solids from final lagoon	1,790	45	100	2,500	2,000	-
	Furnace scrubwater Solids (from concrete settling pit)	1,610	35	70	650	800	-
	Electrostatis precipitator dust from ferrochrome	3,390	54	300	14,000	7,200	-

APPENDIX B

SOLUBILITY TESTS AND OTHER CRITERIA FOR HAZARDOUS WASTE ASSESSMENT

For the land disposed or stored waste streams (i.e.,slags, sludges, dusts, others) from each of the metal smelting and refining categories,an assessment has been made as to whether the wastes are considered either "non-hazardous" at this time or "potentially hazardous" at this time. Hazard ratings were made using a number of criteria including the following:

- Types and concentrations of potentially hazardous constituents (Cd, Cr, Hg, Pb, Zn, Cu, Ni, As, phenol, cyanide, fluoride, oil and grease)

- Physical characteristics of residuals

- Susceptibility to leaching of potentially hazardous constituents as indicated in solubility tests described below.

The mere presence of toxic constituents in significant concentrations in a waste did not automatically result in a hazardous rating. The most important criteria was the tendency of toxic constituents to be leached from residuals at significant concentrations.

Collected samples of slag, sludges, dusts and other wastes believed to be representative of wastes discarded or stored by the metal smelting and refining industries were selected for testing. Particle size distribution of sludges and dusts were comparable to those encountered at disposal sites. Particle size distributions of selected slags ranged from silt size to 1 to 2 inch chunks. Much larger chunks of slag are found at disposal sites. Selected samples probably represent the more comminuted fraction of disposed slags and pot liners.

Approximately 50 grams of each sample was placed in a 200 ml jar and two parts by weight of water added. The bottles were then gently agitated on a rotary tumbling apparatus (approximately 4 RPM) for a period of 72 hours. Samples were then filtered through a 0.45 micron micropore filter and collected filtrate analyzed for trace metals and other parameters of interest. Tables B-1 through B-5 give the results of the chemical analyses of filtrate from the various waste samples after agitation and filtration.

If lead, cadmium, mercury, cyanide, phenol or other highly toxic materials leached at greater than 1 ppm in solubility tests, the waste was designated as potentially hazardous at this time.

TABLE B-1

SOLUBILITY TESTS

Primary Copper, Zinc, Antimony, Mercury, Tungsten and Lead

Chemical Analysis (ppm) of filtrate

Type of Waste	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Zn	Se	pH	Cond.
Primary Copper SIC 3331													
reverberatory slag	0.040	<0.01	<0.01	0.37	<0.02	<0.01	<0.05	0.3	<0.2	0.24	0.09	10.8	600
electric furnace slag	0.052	0.15	0.02	0.58	<0.02	0.2	<0.05	6.0	<0.2	3.0	0.13	7.8	100
converter dust	3.44	170	0.9	31,000	0.030	33	15	8.3	2.0	9,000	<0.05	3.9	<20
acid plant sludge	0.805	8.4	0.5	850	-	1.0	0.64	7.8	<0.2	300	-	3.0	2,700
reverbatory dust	0.300	130	0.1	29,000	0.008	15	2.5	7.3	<0.2	13,000	<0.05	4.2	>10,000
Primary Zinc SIC 3333													
gypsum cake (neutral cooling tower)	0.178	24	0.04	5.4	<0.02	260	0.16	2.1	<0.2	9,600	<0.05	6.4	>10,000
gypsum cake (acid cooling tower)	0.325	11	0.67	25.0	<0.02	550	2.3	1.0	<0.2	9,500	<0.05	1.4	>10,000
anode sludge	0.040	12	0.05	2.0	<0.02	13	0.26	2.0	<0.2	3,050	<0.05	2.5	8,000
retort furnace residue	-	0.04	0.02	0.23	<0.02	65	1.1	0.3	<0.2	230	<0.05	7.1	2,000
cadmium plant residue	0.029	<0.01	0.02	2.4	-	3.7	0.4	9.0	<0.2	4,000	-	6.3	-
oxide furnace residue	-	0.02	<0.01	7.7	<0.02	16	<0.05	0.2	<0.2	78	<0.05	8.2	2,000
acid plant sludge	<0.003	<0.01	<0.01	0.27	<0.02	0.03	<0.05	1.3	<0.2	0.37	<0.05	10.0	<20
Primary Antimony SIC 3339													
blast furnace slag	3.00	0.09	<0.01	5.0	-	0.01	<0.05	<0.2	100	1.7	<0.05	9.2	<20
electrolytic plant sludge	-	0.22	<0.01	0.27	-	0.03	<0.05	0.3	1.6	0.5	-	11.0	>10,000
Primary Mercury SIC 3339													
rotary kiln calcine	-	<0.01	0.03	<0.03	-	<0.01	0.08	<0.2	<0.2	<0.01	0.05	10.4	450

- Not Analyzed

TABLE B-1 (cont.)

Type of Waste	Chemical Analysis (ppm)												
	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Sb	Zn	Se	pH	Cond.
Primary Tungsten SIC 3339													
digestion residue	<0.003	0.15	0.05	90	<0.02	75	60	0.7	<0.2	1.5	<0.05	6.4	>10,000
Primary Lead SIC 3332													
blast furnace slag	<0.003	0.03	<0.01	0.1	<0.02	<0.01	<0.05	<0.2	<0.2	0.22	0.12	6.7	<20
lead fuming slag	0.089	<.01	<0.01	1.0	<0.02	0.03	<0.05	<0.2	1.0	0.64	<0.05	9.2	80
blast furnace dust	0.177	8.0	<0.01	130	<0.02	0.25	0.09	7.3	<0.2	45	<0.05	8.8	<20
sinter scrubber sludge	-	9.1	<0.01	2.6	<0.02	1.3	<0.05	5.5	<0.2	7.5	0.17	6.8	2,500
lagoon dredgings (smelter)	0.231	11	<0.01	0.53	<0.02	27	0.08	4.5	<0.2	9.5	<0.05	6.7	4,000

TABLE B-2

SOLUBILITY TESTS

Secondary Lead and Secondary Copper

Type of Waste	Chemical Analysis (ppm)									
	Zn	Cd	Cr	Cu	Mn	Pb	Sb	Sn	pH	Cond.
Secondary Lead SIC 33413										
scrubber sludge	1.3	5	.05	0.50	0.21	2.5	<0.2	1.6	8.4	>10,000
furnace slag	0.24	<0.01	<0.01	0.68	0.03	<0.2	<0.2	<0.2	9.6	190
furnace dust	4,000	230	12.0	45	4.0	24	<0.2	860	3.9	> 10,000
Secondary Copper SIC 33412										
blast furnace slag	55	1.0	0.03	170	0.3	6	<0.2	<0.2	9.4	90
water treatment sludge	<0.01	0.05	7.1	0.63	0.06	0.5	<0.2	<0.2	8.6	2,000

- Not Analyzed

TABLE B-3

SOLUBILITY TESTS

Ferroalloys

Type of Waste	Chemical Analysis (ppm) Cr	Cu	Zn	Mn	Ni	Pb	Co	pH	Cond.
Ferrochrome SIC 3313									
furnace slag (ferrochrome)	0,02	0,02	0.2	0.3	< 0.05	0.4	-	9.9	100
furnace slag (ferrochrome silicon)	0,28	1.0	110	0,2	< 0.05	15	-	9.9	60
furnace baghouse dust (Fe Cr Si)	190	0,44	0.3	0,1	<0.05	1,5	-	8,8	-
ESP dust (Fe Cr)	710	0,20	0,09	0,07	0,14	0,7	-	12,3	>10,000
Ferronickel SIC 3313									
granulated slag	0,01	0,74	2,0	0,07	< 0,05	1,0	< 0,02	8.5	90
pond dredgings	0,08	0,14	0,1	0,02	< 0,05	0,30	< 0,02	8.8	600
skull plant tailings	0,01	50	64	0,11	< 0,05	<0,2	0,06	11,0	1,000
reject ore	< 0,01	0,10	0,05	0,14	0,70	<0,2	< 0,02	8,0	60
Silicomanganese SIC 3313									
furnace slag	<0,01	0,17	0,05	0,10	< 0,05	<0,2	-	6,8	90
baghouse dusts	0,6	0,37	0,60	2,2	0,27	1,2	-	13,0	-
scrubwater solids	0,55	0,14	0,03	<0,02	<0,05	1,3	-	11,0	< 20
Ferromanganese SIC 3313									
baghouse dust	0,20	4,50	110	7,5	0,53	560	-	9,7	< 20
slag (Fe Mn)	0,02	0,04	0,03	2,1	<0,05	< 0,02	-	5,9	120
Ferrosilicon SIC 3313									
baghouse dust	0,30	0,24	<0,01	0,06	0,10	<0,02	-	9.6	-

- Not Analyzed

TABLE B-4

SOLUBILITY TESTS

Primary and Secondary Aluminum

Type of Waste	Chemical Analysis (ppm)											
	F	Cn	Cu	Zn	Pb	Cr	Mn	Ni	Na	Cl	pH	Cond.
Primary Aluminum SIC 3334												
shot blast dust	-	-	0.14	0.2	< 0.02	< 0.01	20	0.13	-	-	7.4	5,000
spent pot liners	10,400	5,460	-	-	-	-	-	-	-	-	12.6	>10,000
lagoon sludge (pumps)	8.0	-	-	-	-	-	-	-	-	-	8.5	2,500
cryolite recovery sludge ("black mud")	600	83	-	-	-	-	-	-	-	-	9.8	>10,000
Secondary Aluminum SIC 33417												
dross	2.6	-	1.5	<0.01	0.17	0.90	0.37	0.70	30,000	110,000	8.3	>10,000
baghouse dust	16.0	-	0.7	20	0.70	0.04	20	0.34	-	-	7.0	>10,000
high salt slag	97	-	0.8	<0.01	0.24	1.5	0.43	1.6	56,000	200,000	11.0	>10,000

- Not Analyzed

TABLE B-5

SOLUBILITY TESTS

Iron and Steel and Iron and Steel Foundries

Type of Waste	Chemical Analysis (ppm) Mn	Cr	Cu	Pb	Ni	Zn	F	Phenol	Cyanide	Oil & Grease	pH	Cond.
Iron and Steel SIC 3312												
blast furnace slag	< 0.01	<0.01	<0.03	< 0.20	< 0.05	<0.01	1.9	-	-	-	10.6	1,800
open hearth slag	<<0.01	0.01	0.04	0.30	< 0.05	< 0.01	3.1	-	-	-	12.5	8,000
BOF slag	<0.01	0.03	<0.03	0.20	<0.05	<0.01	4.0	-	-	-	12.5	7,000
electric furnace slag	<0.01	0.27	< 0.03	0.44	<0.05	<0.01	1.5	-	-	-	12.4	7,500
soaking pit slag	< 0.01	1.40	0.04	<0.20	<0.05	0.02	-	-	0.38	-	9.5	80
blast furnace dust	0.12	0.03	0.09	0.25	<0.05	0.20	2.2	0.25	< 0.25	-	11.7	5,000
open hearth dust	12	0.03	0.06	0.40	0.40	0.10	19	-	-	-	8.9	6,000
electric furnace dust	0.26	0.34	0.10	150	<0.05	0.70	7.6	-	-	-	12.6	>10,000
blast furnace sludge	0.08	0.02	<0.03	<0.20	< 0.05	<0.01	14.0	0.40	-	-	9.5	1,000
BOF sludge	0.50	0.09	0.09	<0.20	<0.05	0.13	14.0	-	-	-	10.4	-
electric furnace sludge	0.03	94	0.17	2.0	<0.05	0.06	11.0	-	-	-	11.5	800
mill scale	<0.01	0.05	0.03	<0.2	<0.05	0.03	-	-	-	0.5	9.6	80
decanter tar sludge (coke byproduct plant	< 0.01	< 0.01	<0.03	<0.2	<0.05	< 0.01	-	~500	0.59	198	8.9	350
ammonis still lime pit sludge (coke byproduct plant)	0.05	0.02	0.09	0.5	<0.05	<0.01	-	20	198	-	11.5	>10,000
Iron and Steel Foundry SIC 332												
furnace slag	0.06	0.05	0.25	<0.20	<0.05	0.12	-	-	-	-	10.6	60
furnace dust (cyclone)	0.01	0.03	0.15	<0.20	<0.05	< 0.01	-	-	-	-	9.5	2,500
furnace dust (baghouse)	4.5	0.03	0.19	0.20	<0.05	<0.01	-	-	-	-	8.5	>10,000
shotblast dust	0.05	< 0.01	0.06	< 0.20	<0.05	0.09	-	-	-	-	10.5	650
spent sand	4.0	0.03	0.09	< 0.20	0.20	1.2	-	0.4	-	-	3.3	2,000
sand reclaimer dust	0.18	< 0.01	< 0.03	< 0.20	< 0.05	< 0.01	-	0.4	-	-	8.5	350

- Not Analyzed

Some leeway was allowed depending on the physical nature of the waste material and the constituents found to solubilize. Thus many materials solubilized manganese in the range of a few to 50 or 100 ppm. Leaching of manganese alone was not considered sufficient reason to designate a waste as potentially hazardous since manganese is relatively non-toxic. Manganese is highly abundant in soils and rocks and is present to an average extent of 850 ppm in soils with ranges of 100 to 4,000 ppm (Ref. 1).

Fluoride is beneficial to teeth at low concentrations as evidenced by the use of fluoridated toothpastes and fluoridated water supplies. The average concentration of fluorine in soils is 200 ppm with a range of 30 to 300 ppm (Ref. 1). Leaching of fluoride of up to 20 ppm in iron and steel making slags, sludges, and dusts was not considered sufficient to designate these wastes as potentially hazardous if there was less than 1 ppm leaching of other potentially hazardous constituents.

Although leaching of sodium, potassium and chloride from wastes would not ordinarily constitute a hazardous waste problem in the metal smelting and refining industry, the extremely high concentration of these constituents in "high salt slag" from the secondary aluminum industry and their high solubility pose a definite threat to groundwater quality. High salt slag is therefore considered potentially hazardous.

The only residual which leached a heavy metal at significant concentration and was not considered potentially hazardous at this time was retort residue from primary zinc smelting. This slag residue leached zinc at 230 ppm in a solubility test. Zinc is required in human diets at 10-40 ppm and has low toxicity. Further testing of the leachability of zinc and other metals from zinc retort residue is needed for further evaluation of toxicity.

The limitations of the solubility tests conducted must be recognized. Only one solubility test was conducted on each residual. Replications are desirable to establish statistical significance of test results. The leaching solution in all cases was distilled water at pH 5.5. Thus no information is available from these tests on the quality of leachate at lower or higher pH's.

REFERENCES

1. "Agronomic Controls Over Environmental Cycling of Trace Elements," W.H. Alloway in Advances In Agronomy 20:235-274, 1968.

APPENDIX C

COSTS AND COSTS FACTORS FOR TREATMENT AND DISPOSAL TECHNOLOGIES

The predominant practices used in the United States smelting and refining industry for on land storage or disposal of process and pollution control residuals are on land storage or disposal of slags, dusts and dredged sludges, and storage or permanent disposal of slurries and sludges in lagoons. Practices considered for adequate health and environmental protection include the use of lined lagoons, chemical fixation of land disposed sludges, soil sealing at disposal areas and collection of runoff. The basic costing assumptions used in estimating the costs of the above practices are described here. All costs are in 4th quarter 1973 dollars.

Capital Costs

Lagoons. Lagoons are assumed to be rectangular in shape with the bottom length twice the bottom width. The dikes of the lagoons form a 27^{o} angle with the ground surface. In the construction of the dikes, excavation of the interior area is to a depth sufficient to provide all the material needed for the construction of the dikes. The earth is assumed to be sandy loam with granular material. The width of the top of the dikes is 3 meters.

Three programs were developed to facilitate the computation of factors used for estimating lagoon costs.

Program No. 1

Inputs	Outputs
Lagoon volume	Bottom width
	Top width
	Bottom length
	Top length

Program No. 2

Inputs	Outputs
Bottom width	Volume
Bottom length	
Depth	

Program No. 3

Inputs	Outputs
Depth of excavation	Dike circumference 1)*
Height of dike above ground level	Volume of material in dike
Width on top of dike	Total width
Bottom width	Total length
Bottom length	Total area

1)* Measured along center line of dike.

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The initial input is the required lagoon volume. Program No. 2 computes the volume of material obtained by excavation to varying depths. It is used jointly with Program No. 3 to determine the depth of excavation necessary to provide sufficient material for dike construction.

Cost categories and cost factors used to estimate lagoon costs are noted below.

Site Preparation		Ref.
Survey	$ 625/ha	(1)
Test drilling	24.60/m for 10m hole	(1)
Sample testing	62.50/sample	(1)
Report preparation	1,200-2,400	(2)
Construction		
Excavation & forming	$ 1.33/m^3	(1)
Compacting with Sheeps Foot	1.85/m^3	(1)
Fine grade finishing	0.45/m^2	(1)
Soil conditioning	1.24/m	(3)
Transverse drain fields	4.60/m	(1)

Survey is assumed to be performed by standard transit and chain. The number of test holes drilled is varied as function of lagoon size; at least two are drilled in all cases. Two soil samples per test hole are analyzed. Report preparation is assumed to require 1 to 2 engineering man-weeks depending on the size of the project.

Excavation, forming and compacting costs are based on the volume of material in the dike. Fine grade finishing is computed from the dike surface area, i.e. the product of the perimeter of the cross section of the dike and its circumference. Soil conditioning cost is a function of the dike circumference.

Drain fields are designed to monitor lagoon leakage. They are assumed to be of 1/3 m^2 cross section and are located at 30m centers along the length of the lagoons. The excavation cost is $1.50/m (1) and 1 m^3 of gravel at a delivered cost of $9.30/$m^3$ (1) is used for every 3 m of ditch.

Several cost categories listed for lagoons, such as survey and excavation and forming, also apply to other facilities. The same unit costs are employed in these cases.

Lagoon Liners. Lining of lagoons is specified for some industries for Level II and is employed extensively in Level III. There are many candidates for liner material. Hypalon, a frequently used liner material, is selected. Two cost sources (4) and (5) provide ranges of costs for the purchase and installation of the liner. The two data sources coincide closely in their estimates. The value selected is $\$4/m^2$ installed.

Other Facilities & Activities

Concrete Work. A number of industries use concrete-lined pits for temporary retention and settling of sludges and slurries. A floor thickness of about .2 m is assumed for all cases. It's cost in place is $\$15.35/m^2$ (1). The required wall thickness is a function of volume of contained material and is assumed to be 0.4 m in this study. Wall costs are computed on the basis of $\$243.75/m^3$ (1) of concrete in place.

Ground Sealing. Sealing of the ground at dump sites to prevent leaching is stipulated for many industries as Level III protection. The sealing material of choice is bentonite clay. Approximately 14.7 kg/m^2 (3 lbs/ft^2) are worked into the top layer of soil. The FOB cost of bentonite is \$.09/kg (\$.04/lb (5). An average transportation cost of \$20 MT ($0.32/M^2$) (4) is added.

Installation includes disking, spreading and compacting. These tasks are assumed to be equivalent to the fine grade finishing specified in lagoon construction and a cost of $\$0.45/m^2$ is used. The total cost is [(\$0.09 x 14.7 kg/m^2) + $\$0.45/m^2$ + $\$0.32/m^2$] or $\$2.09/m^2$. A cost of $\$2.00/m^2$ is used in the study.

Collection Ditches. Ditches are installed to collect runoff from dump perimeters. Excavation and installation of 6" perforated, vitrofied pipe yields a cost of \$10.10/m of ditching (1). All open dumps are assumed to be square; some slanting of the ground is assumed. Unless specified otherwise, the length of ditching installed equals 1.5 x 1 side of the dump area.

Pumps and piping to transport the collected water are discussed under stationary equipment.

Railroad Track. Intra-plant rail transport is employed by some industries to haul solid or liquid waste from the plant to an on-site dump. The construction cost for 1 km of track is shown below. It is a single track on level ground.

	Ref.	
Survey ($625/ha)	(1)	$ 250
Miscellaneous bulldozing ($1.33/$m^3$)	(1)	2,080
Base prepare & roll sub-base ($.52/$m^2$)	(1)	1,145
Track		
100 lb rail ($19.70/m)	(1)	19,700
Spikes plates & bolts ($7.90/m)	(1)	7,900
Timber ties ($13.10/m)	(1)	13,100
Ballast ($9.50/m)	(1)	9,500
Labor ($31.65/m)	(1)	31,650
Total		$ 85,325/km

The width of the sub-base is assumed to be 4 m. The miscellaneous bulldozing represents 2 days work and movement of about 860 m^3 of earth.

Road Construction. A road must be provided where waste transport is in by truck in lieu of rail. The cost of constructing a gravel road 1 km in length is as follows:

Survey ($625/ha)	(1)	$ 375
Miscellaneous bulldozing ($1.33/$m^3$)	(1)	1,145
Base prepare & roll sub-base ($.52/$m^2$)	(1)	3,120
Base course select gravel ($3.29/$m^2$)	(1)	19,740
Compaction ($.57/$m^2$)	(1)	3,420
Culverts ($41.60/m)	(1)	2,500
Drainage ditching ($2.25/m)	(1)	2,250
Total		$ 32,550/km

The road width is 6 m. A base course of gravel about .3 m deep is applied and compacted. Culverts, each 6 m in length, are assumed to be required every 100 m. Drainage ditches are provided for a distance of .5 km along both sides of the road. The miscellaneous bulldozing is the same as is included for railroad track construction.

Stationary Equipment

Slurry Pump. Slurry pumps can be used in lieu of draglines for dredging lagoons. The selected slurry pump has a capacity of 236 liters per minute and is powered by a 2 hp motor. Its cost including housing, installation, wiring and piping is $13,730 (6).

Both rigid, installed and flexible piping are used. Both are 7.6 (3" pipe). Their costs/m are $17.30 (1) and $4.40 (1), respectively.

Other Pumps. The main application of other pumps is at the on-site slag dumps to pump collected runoff water. Centrifugal pumps requiring no attendants are used. The pump capacities are selected as a function of the size of the dump. They are sized to handle a volume of water equivalent to a 2.5 cm rainfall/hr over the dump area.

The pump costs are based on Reference (7). A 3 m head is assumed. Piping costs associated with the pumps include 100 m each of rigid, installed and flexible pipe. Horsepower requirements for "other pumps" are computed as follows:

$$HP = \frac{GPM \times H}{3960 \times E}$$

where

HP = Horsepower
GPM = Gallons/min
H = Head (assumed to be 9.8 ft (3 m)
E = Efficiency (assumed to be = .9)

Belt Conveyors. A belt conveyor is used in one industry to transport slag to a slag pile. A number of conveyors are positioned in series because of the distance involved. A 36" wide belt conveyor was found sufficient to handle the waste produced. Its cost, is $44,545/30 m (100 ft) section, installed (Ref. 7 and 9).

Mobile Equipment. Generic equipment types are identified and costed for handling and trasnporting waste products. These do not necessarily represent optimum equipment in terms of capacity, power or cost. Equipment specified includes:

			Ref.
Dump truck (16-18 t)	$ 25,000		(2)
Tank truck	40,000		(2)
Front loader and backhoe	20,000	(similar to JD-410)	
Bulldozer	16,000	(similar to JD-350)	
Dragline with 3/4 yd clam shell	70,000		(2)
Yard engine (industrial)	30,000	(used)	(2)
Hopper car (45 t)	5,000	(used)	(2)
Ladle car (10,8 m^3)	40,000		(2)

Many plants do not require particular equipment full time for waste handling and transport. The approximate fraction of time a piece of equipment is actually needed for these purposes is determined and the capital cost is assigned accordingly. It is assumed that the equipment is engaged in other plant activities the remainder of the time. The fraction of use is based on an 8 hour/day or 2,000 hr/yr equipment availability.

Land. Three categories of land are considered. They are shown below together with their estimated costs.

		Ref.
Rural	$ 1,750/ha	(6)
Semi-industrial	3,955/ha	(6)
Improved industrial	24,710/ha	(6)

Annual Costs

Lagoons, Construction and Other Facilities. A twenty year useful life and a corresponding amortization period are postulated. It is assumed that equal quarterly payments are made throughout this time resulting in the following annual cost.

$$C_A = B \times \frac{\frac{r}{m}\left(1 + \frac{r}{m}\right)^{Nm}}{\left(1 + \frac{r}{m}\right)^{Nm} - 1}$$

where

C_A = Annual amortization cost
B = Initial amount
r = True annual interest rate (10%)
m = No. of payments per year (4/year)
N = No. of years (20 years)

The computed annual cost essentially represents the sum of the cost of capital and depreciation.

Additionally, a cost category is included for the repair and maintenance of lagoons, facilities and other construction. This cost is estimated to be 3 percent annually of initial construction cost (excluding site preparation) except for railroad tracks and roadways for which a 5 per cent annual rate is used.

Mobile and Stationary Equipment. Annual equipment costs are treated in the same manner as lagoons, construction and other facilities. A ten year useful life is assumed for stationary and road mobile equipment and a twenty year life for railroad equipment. Pumps and piping are considered stationary equipment.

The annual maintenance and repair cost is estimated as 5 per cent of initial purchase (7) cost exclusive of fuel and operating personnel.

Land. Annual land cost represents an opportunity cost. It is on 10 per cent of initial acquisition cost. Survey costs associated with land used for slag and other dumps are added to and amortized together with lagoon construction and other facility costs.

Operating Personnel. Waste handling and transport is performed by two labor grades: heavy equipment operator and truck driver/laborer. The applicable hourly wage rates are $12.15 (1) and $9.45 (1) respectively. The rates include fringe benefits, overhead and supervision.

Personnel costs are charged only for the hours such personnel are actually handling and transporting wastes. It is assumed that personnel will be employed in other plant activities the remainder of their time.

Energy. Energy costs are divided into two categories: fuel and electricity. All mobile equipment is assumed equipped with diesel engines. Fuel consumption by a particular equipment unit can vary widely depending on its operational use. Based on a brief review of engine specifications the following mean fuel consumption values were determined.

Trucks	4 Gal/Hr
Bulldozer	2.4 Gal/Hr
Front loader and backhoe	2.85 Gal/Hr
Dragline with 3/4 yd clam shell	2.85 Gal/Hr
Yard engine	8 Gal/Hr

The cost of fuel is $0.40/gal.

The cost of miscellaneous electric energy, (e.g. lighting) is estimated at 10 per cent of fuel cost.

The power cost of electric equipment, where specified, is computed separately as follows:

$$\text{Cost per horsepower year} = \frac{\text{horsepower of motor}}{0.9\ (\text{efficiency}) \times 0.9\ (\text{power factor})} \times$$

0.7457 x No. of yearly operating hours x cost per kilowatt hour. A kilowatt hour cost of $0.012 is assumed.

Chem-Fix Operation. Chemical fixation where employed is shown as an annual cost. At this time, no data was found describing capital costs to establish this process for various sizes of operations. The cost of $13.20/$m^3$ of waste treated which is used in the study reflects current experience (10).

Taxes. Taxes are computed as 2.5 per cent of the cost of land (6).

Insurance. Annual insurance premiums are 1 per cent of the capital cost (6).

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(7) Capital and Operating Costs of Pollution Control Equipment Modules - Vol. II - Data Manual, EPA-R5-73-023b, Socioeconomic Environmental Studies Series, Office of Research and Development, USEPA, July 1973.

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(10) Data provided by Chemfix Corporation.

APPENDIX D

PROCEDURES FOR CALCULATING WASTE QUANTITIES FOR THE IRON AND STEEL INDUSTRY

This appendix uses the iron and steel industry as an illustrative example of the methodology employed to estimate the quantities of wastes and potentially hazardous constituents therein. Similar procedures were employed for estimating waste quantities in the other primary and secondary smelting and refining sectors. Most of the data required for calculating the amounts of wastes generated by iron and steel mills were derived from: 1) the collection and analysis of waste samples; 2) information provided by environmental control personnel at ten participating steel mills; 3) the Iron and Steel Works Directory of the United States and Canada (1974); and 4) the Annual Statistical Report, American Iron and Steel Institute (1973). The Directory and the Annual Statistical Report were used primarily in estimating the production of various types of facilities by state.

Through the cooperation of the American Iron and Steel Institute, arrangements were made to have ten integrated steel plants participate in a program to collect waste samples from selected facilities on a daily basis over a four week period, and to provide quantitative information on the amounts of waste generated. Each of the ten plants was visited to discuss the types of waste generated and to identify 10 to 15 waste sources to be included in the sampling program. The waste samples were collected by steel plant personnel and forwarded to Calspan Corporation for analysis. Wastes of each type were composited on a weekly basis, so that for each plant, four composite samples (one for each week of the sampling program) were obtained for each type of waste of interest. The analyses included determinations of chromium, copper, manganese, nickel, lead, zinc, cyanide, fluorine, oil and grease, and phenol. For any given waste type (e.g., electric furnace dust) the concentration values were averaged over all plants and over all composites.

Subsequent to each plant visit, a form indicating desired information on the quantities of waste generated was prepared and sent to the environmental control manager. Specific information of interest was the total annual production for each facility and the amounts of waste of each type produced (e.g., dust, sludge, slag). The data provided from all plants were analyzed and average waste generation factors were obtained. Table D-1 summarizes the averaged data for the quantities of each waste type generated and the concentrations of constituents of interest.

The production data for the major steel plant products (e.g., pig iron, ingot steel, cold rolled steel, etc.) and the waste generation factors for the associated facilities allows the total waste quantities to be determined. Data for a "typical" plant were presented in the main text and are reproduced here as Table D-2. Thus, for example, the yearly quantity of basic oxygen furnace slag for a typical plant is calculated as:

TABLE D-1

WASTE GENERATION FACTORS - IRON & STEEL PLANTS

Type of Waste	Generation Factors		Concentration Factors (ppm)						
	Kg/MT of Steel Produced or Processed	Kg/MT of Facility Output	Cr	Cu	Mn	Ni	Pb	Zn	Oil & Grease
Coke Oven - Sludge	2.6*	5.5	10.0	4.0	102	5.5	30.5	96.5	203,070
Blast Furnace - Slag	250*	348	46.9	21.9	3000	<7.5	21.5	8.2	--
Blast Furnace - Dust	11.7*	16.2	92.4	93.2	8800	57.6	302	516	--
Blast Furnace - Sludge	17.6*	24.4	56.1	37.4	3700	38.4	1210	11,650	--
Basic Oxygen Furnace - Slag	145	145	1290	31.3	41,600	12.2	12.0	16.2	--
Basic Oxygen Furnace - Dust	16.0	16.0	315	202	11,400	115	7350	3350	--
Basic Oxygen Furnace - Kish	0.14	0.14	110	45.7	3810	56.6	137	660	--
Basic Oxygen Furnace - Sludge	17.3	17.3	708	174	10,300	130	4190	10,094	--
Open Hearth Furnace - Slag	243	243	2360	49.8	42,710	23.7	57.4	47.9	--
Open Hearth Furnace - Dust	13.7	13.7	568	1130	4810	314	11,650	113,000	--
Electric Furnace - Slag	120	120	4820	79.0	50,580	53.9	32.7	80.5	--
Electric Furnace - Dust	12.8	12.8	1380	1940	42,610	246	24,220	95,710	--
Electric Furnace - Sludge	8.7	8.7	2690	1130	34,100	421	7900	13,540	--

*Approximately 0.72 MT of pig iron required to produce 1 MT of steel (on the average). Approximately 0.66 MT of coke required to produce 1 MT pig iron. Coke oven sludge consists of ammonia still lime sludge and decanter tank tar.

TABLE D-1 (cont.)

WASTE GENERATION FACTORS - IRON & STEEL PLANTS

Type of Waste	Generation Factors		Concentration Factors (ppm)						
	Kg/MT of Steel Produced or Processed	Kg/MT of Facility Output	Cr	Cu	Mn	Ni	Pb	Zn	Oil & Grease
Soaking Pit - Slag	35.2	35.2	373	278	5280	117	760	59.3	--
Primary Mill - Sludge	1.87	1.87	--	--	--	--	--	--	--
Primary Mill - Scale	44.9	44.9	318	449	5410	385	58	32.5	10,180
Continuous Caster - Sludge	0.104	0.104	--	--	--	--	--	--	--
Continuous Caster - Scale	8.7	8.7	--	--	--	--	--	--	--
Hot Rolling Mill - Sludge	1.74	1.74	198	232	3280	253	1050	669	45,290
Hot Rolling Mill - Scale	18.3	18.3	208	274	3170	545	154	26.9	42,246
Cold Rolling Mill - Sludge	0.16	0.16	--	--	--	--	--	--	--
Cold Rolling Mill - Scale	0.052	0.052	--	--	--	--	--	--	--
Cold Rolling Mill - Waste Pickle Liquor	22.8	22.8	12.7	7.35	179	19.2	1.1	8.3	63.9
Tin Plating Mill - Sludge	5.32	5.32	2760	2730	1040	250	688	2260	--
Galvanizing Mill - Sludge	10.8	10.8	--	--	--	--	--	--	--
Galvanizing Mill - Waste Pickle Liquor	5.17	5.17	--	--	--	--	--	--	--

TABLE D-2

YEARLY GENERATION OF RESIDUALS BY TYPICAL IRON AND STEEL PLANT*

	Total Quantity of Waste (MT)	Quantity of Potentially Hazardous Constituents (MT)						
		Cr	Cu	Mn	Ni	Pb	Zn	Oil & Grease
Coke Oven - Sludge	6,200	0.062	0.025	0.628	0.034	0.188	0.594	1250
Blast Furnace - Slag	557,000	26.1	12.2	1670	<4.2	12.0	4.57	--
Blast Furnace - Dust	25,900	2.40	2.42	228	1.49	7.83	13.4	--
Blast Furnace - Sludge	39,000	2.19	1.46	144	1.50	47.2	455	--
Basic Oxygen Furnace - Slag	290,000	374	9.08	12064	3.54	3.48	4.70	--
Basic Oxygen Furnace - Dust	280	0.031	0.013	1.07	0.016	0.038	0.185	--
Basic Oxygen Furnace - Sludge	34,600	24.5	6.02	356	4.50	145	349	--
Electric Furnace - Slag	60,000	289	4.74	3035	3.23	1.96	4.85	--
Electric Furnace - Dust	6,400	8.83	12.4	273	1.57	155	613	--
Electric Furnace - Sludge	4,350	11.7	4.92	148	1.83	34.4	58.9	--
Soaking Pit - Slag	54,900	20.5	15.3	290	6.42	41.7	3.26	
Primary Mill - Sludge	2,520	--	--	--	--	--	--	--
Primary Mill - Scale	60,600	19.3	27.2	328	23.3	3.52	1.97	617
Continuous Caster - Sludge	82.2	--	--	--	--	--	--	--
Continuous Caster - Scale	6,900	--	--	--	--	--	--	--

TABLE D-2 (cont.)

YEARLY GENERATION OF WASTE RESIDUALS BY TYPICAL IRON AND STEEL PLANT

Type of Waste	Total Quantity of Waste (MT)	Quantity of Potentially Hazardous Constituents (MT)						
		Cr	Cu	Mn	Ni	Pb	Zn	Oil & Grease
Hot Rolling Mill - Sludge	3,130	0.620	0.727	10.3	0.792	3.29	2.10	141
Hot Rolling Mill - Scale	32,900	6.85	9.03	104	18.0	5.07	0.886	1392
Cold Rolling Mill - Sludge	112	--	--	--	--	--	--	--
Cold Rolling Mill - Scale	36.4	--	--	--	--	--	--	--
Cold Rolling Mill - Waste Pickle Liquor	16,000	0.203	0.117	2.86	0.306	0.018	0.132	1.02
Tin Plating Mill - Sludge	532	1.47	1.45	0.553	0.133	0.366	1.20	--
Galvanizing Mill - Sludge	1,350	--	--	--	--	--	--	--
Galvanizing Mill - Waste Pickle Liquor	646	--	--	--	--	--	--	--

* Quantities calculated from generation and concentration factors given in Table D-1 based on annual production figures given in Table 4 of Volume III. Divide by 365 to obtain daily quantities. Multiply by 1.1 to convert to short tons.

$$\text{quantity BOF slag/yr} = \text{generation factor } \frac{\text{MT}}{\text{MT}} \times \text{steel production (MT)}$$

$$= \frac{0.145 \text{ MT}}{\text{MT}} \times 2{,}000{,}000 \text{ MT}$$

$$= 290{,}000 \text{ MT}$$

The amount of potentially hazardous constituents in the BOF slag of the typical plant is calculated as:

$$\text{quantity potentially hazardous} = \text{quantity BOF slag/yr (MT)} \times \text{concentration factor potentially hazardous constituent}$$

The quantity of chrome as an example is calculated as:

$$\text{quantity BOF slag} \times \text{concentration factor for chromium}$$

$$290{,}000 \text{ MT} \times \frac{1290 \text{ MT}}{10^6 \text{ MT}}$$

$$= 374 \text{ MT}$$

In order to calculate waste generation quantities on a state-by-state basis, production figures for various product types had to be determined. Since such data were not directly available, estimates had to be generated. For each state, iron and steel production and/or processing facilities were tabulated using the Iron and Steel Works Directory of the United States and Canada (1974). From the size and number of facilities of each type listed for all plants in a given state, production figures were estimated for that state. These figures were summed over all states and comparisons made with total U.S. production data presented in the Annual Statistical Report, American Iron and Steel Institute. The figures for the individual states were then adjusted to make the national total agree with the published national figures.

The wastes for the state totals were grouped into five categories: slag; dust; sludge; scale; and pickle liquor. The sources for each waste category are listed in Table D-3. In computing the total quantities of waste in each category for each state, the waste factors discussed previously were used with weighting factors as appropriate. The weighting factors are necessary in some cases to account for the fact that any one type of facility might produce different waste types depending on the type of control system used. For example, basic oxygen furnaces might employ dry- or wet-type emission control systems. A dry system produces dust-type waste, whereas, a wet system produces a sludge-type waste. Therefore, in order to calculate the amounts of dust and sludge produced by BOF

TABLE D-3

Major Sources of Waste

Waste Category				
Slag	Dust	Sludge	Scale	Pickle Liquor
Blast Furnaces	Blast Furnaces	Coke Ovens	Primary Mills	Cold Mills
BOF's	BOF's	Blast Furnaces	Continuous Casters	Galvanizing Mills
Open Hearths	Open Hearths	BOF's	Hot Finishing Mills	Tin Mills
Electric Furnaces	Electric Furnaces	Open Hearth's	Cold Mills	
Soaking Pits		Electric Furnaces		
		Primary Mills		
		Continuous Casters		
		Hot Finishing Mills		
		Cold Mills		
		Tin Mills		
		Galvanizing Mills		

facilities given the total amount of steel produced in BOF's, the percentages of steel made in BOF's using wet emission control systems and dry control systems must be known. The weighted waste generation factors were then computed by multiplying the waste generation factor for a given type of waste (see Table D-1) by the fraction of product made using that type of control system. The required fractions were estimated from data obtained from the participating plants.

For the final determinations of total wastes (and their constituents) for each state, a program was written to allow the required summations to be computerized. The computed waste values are given as

$$W_k = \sum_{i=1}^{n} f_i \; c_{ik} \; P_i$$

where W_k is the amount of constituent of type k, f_i is the weighted waste generation factor for the i^{th} source (or facility), c_{ik} is the concentration of the k^{th} constituent in the waste generated by the i^{th} source, and P_i is the total annual state-wide production of facilities of the i^{th} type. The total waste quantities, as opposed to the individual constituents, correspond to $c_{ik} = 1$.

To illustrate the application of the above equation, let us consider a specific example for the iron and steel industry, namely, the amounts of dust generated in Pennsylvania. The four major sources of waste dust in the production of iron and steel are: blast furnaces, basic oxygen furnaces, open hearth furnaces and electric furnaces. Table D-4 lists the estimated 1974 production figures (P) for the State of Pennsylvania for each of these facilities and indicates the type of dust. The raw generation factors listed for waste dust are those given in Table D-1. The weighted dust factors (f) were obtained by multiplying the raw waste factors by a fraction representing the estimated percentage of the facilities of each type that utilize dry emission control systems. Specifically, it is estimated that 35 percent of the BOF's, 75 to 80 percent of the open hearths, and 90 percent of the electric furnaces control emissions with dry systems. In the case of blast furnace flue dust and BOF "kish", the raw generation factors were assumed to apply to all facilities. The chromium concentrations (C_c) for each of the listed dusts are also given in the Table.

In accorance with the equation given above, the amount of each dust type for a given facility is determined by taking the product $W_T = P \times f \times C$, with $C = 1$. Thus, to determine the amount of blast furnace flue dust, we compute (21,160,000 metric tons) x (0.0162) = 342,792 metric tons. To determine the amount of chromium in this amount of blast furnace flue dust, we take the product $W_c = P \times f \times C_c$ = (21,160,000) x (0.0162) x (92.4×10^{-6}) = 31.67 MT. Similarly, we obtain the amounts of dusts and the associated chromium content for all of the indicated dust types. The total

TABLE D-4

EXAMPLE OF WASTE GENERATION COMPUTATIONS

STATE - Pennsylvania
WASTE - Dust (Iron and Steel Production)
YEAR - 1974

Facility and Type of Dust	P Facility Production (Metric Tons/Yr)	Raw Dust Generation Factors (MT/MT Product)	f Weighted Dust Factors (MT/MT Product)	C_c Chromium Concentration (ppm)	W_T Total Dust Generated (Metric Tons)	W_C Total Chromium Content of Dust (Metric Tons)
Blast Furnace (Flue Dust)	21,160,000	0.0162	0.0162	92.4	342,792	31.67
BOF (Flue Dust)	15,200,000	0.016	0.0056[1]	315	85,120	26.81
BOF (Kish)	15,200,000	0.00014	0.00014	110	2128	0.23
Open Hearth (Flue Dust)	11,900,000	0.0137	0.0105[2]	568	124,950	70.97
Electric Furnace (Flue Dust)	4,500,000	0.0128	0.01152[3]	1380	51,840	71.54
				Totals	∿607,000	∿201

Notes: 1) Assumes 35 percent of BOF's have dry emission control systems.

2) Assumes 75-80 percent of open hearths have dry control systems.

3) Assumes 90 percent of electric furnaces have dry control systems.

dust is the sum of the amounts for the individual facilities. After rounding, we find the total amount of dust generated in 1974 by integrated iron and steel mills in Pennsylvania to be 607,000 metric tons. The corresponding chromium content of this dust is 201 metric tons. In a similar manner, we determine the amounts of other constituents of interest, namely, copper, manganese, nickel, lead, zinc, cyanide, fluorine, and phenol. The total amount of "potentially hazardous constituents" is then the sum of the individual constituents.

μσ1538
SW-145c.4